Photometry In Staring Imaging

Taking full advantage of sampling the Illumination and viewing geometry dependence of the radiance inherent in staring imaging

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DEM fronts Images Provide Knowledge of Local Slopes of ‘Facets’

- Reconstructing topography (DEM) from multiple images of a target from different viewpoints uses shifts in the positions of features between images to determine their elevations.

- Once the DEM is determined, the signal (DN) in each pixel of the same images is a measurement of the radiance $I$ for the local illumination $i$, emission $e$, and azimuth $A$ angles for each resolved facet of the DEM in each image.

\[
\frac{I}{F}(i, e, A; \lambda) \text{ depends on the composition and physical structure of the facet.}
\]

- Facet dimension is determined by the number of DEM points needed to define the facet normal with sufficient accuracy (gradient of DEM).

- Effects of roughness on scales smaller than the facet contribute to $I / F$ of the facet. (Amit Mushkin’s talk)
Example: I / F of a Snow Facet

Data from Dumont et al (2010) *Atmos Chem Phys* 10, 2507-20. (Best I/F lab measurements)

Nearly new snow - Weak cohesion
*Surface:* dendritic fragments
*Depth:* Stellar crystals and fragmented particles, $\rho=0.19$ g cm$^{-3}$

Snow is *black* at $\lambda=1.5\mu$m, except for large i and e for $A\sim180^\circ$ where there is a strong forward scattering enhancement.

This enhancement is also seen at $\lambda=0.7\mu$m where snow is white, but it contributes only a portion of I/F.

What could cause this forward scattering enhancement in I/F?
Specular (Fresnel) reflection on scales $\lambda \ll d \ll \text{facet}$ from random rough ice surface has similar variation with scattering geometry. (Alternate possibility: strongly forward scattering particles).

Need to look at large emission angle in the sunward direction (large phase angle) to see this (analogous to this sun on the ocean image).

Could potentially use to determine $\gg \lambda$ roughness of facet which may be applicable across spectrum.

This large phase angle geometry is rarely targeted.
Sastrugi and Penitentes

http://www.dreamsofmountains.co.uk/winter2009-10/20100310Sastrugi.jpg

http://www.panoramio.com/photo/49439172

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Albedo and Power Input

Albedo is the integral of the scattered radiance over the upper hemisphere and all wavelengths. Power absorbed is proportional to \([1 – A(i)]\)

\[
\text{Albedo} = \frac{\text{Power Out}}{\text{Power In}}
\]

Both the angle and \(\lambda\) dependence of \(I/F\) are essential inputs to accurately determining the albedo.
Conclusions

• Staring imaging and DEM generation from the images promises to increase our knowledge of I/F by a large factor by removing topographic effects and providing I/F measurements over the range of illumination and viewing geometries in the image set at little to no cost.

• A broad a range of scattering geometries, particularly large phase angles, is desirable for determining I/F, albedo and constraining the surface particles/structures/roughness.

• Estimates of the total power absorbed will be improved if I/F is measured for the range of wavelengths spanning the solar spectrum.

• Combination of I/F and albedo measurements (solar input driver) with self-consistent measurements of volume changes (surface response) from DEMs is a powerful advantage of staring imaging approach.
Supplementary Slides
Representative single scattering ‘phase function’ for a particle

**Top:** Schematic polar plot of scattering by a particle with photons incident from the left. The scattering angle $\Theta$ measures the change in direction of propagation of a photon and $p(\Theta) \, d\Omega$ the probability of scattering into solid angle $d\Omega$ in direction $\Theta$.

**Bottom:** Polar plot of the measured $p(\Theta)$ for irregular olivine M particles ($\text{reff} = 2.6 \, \mu m$) from Muñoz et al (2000).